7. INCORPORATING UNCERTAINTY

Q. DO UTILITIES COMMONLY ADDRESS UNCERTAINTY IN THEIR RESOURCE PLANNING STUDIES?

A. Yes. Electric utility planning studies in recent years have addressed uncertainty systematically through the use of scenario, sensitivity and decision tree analyses. Techniques have been applied where key uncertain variables are represented by probability distributions rather than simple deterministic projections. One Oak Ridge National Laboratories (ORNL) report for the U.S. Department of Energy concluded that:

> Uncertainty is a critical factor that must be considered in utility planning and decision making. Planning only for the base case is too risky. (*Uncertainty in Long-Term Resource Planning for Electric Utilities*, ORNL/CON-272, 1988)

Q. HOW DO THE UNCERTAINTIES IN DECOMMISSIONING PLANNING COMPARE WITH UNCERTAINTIES IN UTILITY RESOURCE PLANNING GENERALLY?

A. I believe that decommissioning is subject to uncertainties equal to or greater than those typically confronted in electric utility resource planning.

Q. WHAT ARE THE KEY UNCERTAINTIES THAT ARE FACED WITH REGARD TO DECOMMISSIONING PLANNING?

A. Two of the key uncertainties are the ultimate cost of decommissioning and the timing of plant retirement.

Q. DOES THE APPLICATION OF AN APPROPRIATE CONTINGENCY FACTOR

RLS-4

State of New Hampshire

Nuclear Decommissioning Finance Committee

Docket No. 93-001

Seabrook Nuclear Facility Decommissioning

Direct Testimony

of

Bruce Biewald and William W. Dougherty

on behalf of the

Office of Consumer Advocate

September 14, 1994

Tellus Institute
Boston, Massachusetts 02116

The Company should revise the decommissioning estimate to include the costs associated with:

- operating and maintaining the spent fuel pool for an additional 34 months starting in January 2029, and
- operating and maintaining the dry cask storage facility between November 2026 and the date the last fuel assembly is accepted by the DOE.

I estimate the additional cost for these operations to be approximately $70.4 million in 1993 dollars, or $72.6 million in 1994 dollars (assuming a 3 percent inflation rate). This amount should be added to the current decommissioning cost estimate.

Second, the Company's cost estimate should be adjusted to include an overall contingency factor. The Company's estimate currently includes contingencies on a line item basis -- amounting to a total contingency factor of 17.14 percent on a weighted basis. This factor provides for routine events such as bad weather and tool breakage. It does not provide for developments that are likely to increase the scope and the cost of the project such as changes in regulatory requirements. It is appropriate -- indeed necessary if a realistic cost estimate is the goal -- to include an *overall* contingency factor as well as the line item contingency factors. I recommend that 20 percent be used.

Key Findings

Q. PLEASE SUMMARIZE YOUR PRINCIPAL FINDINGS.

A. First, because experience in decommissioning large commercial nuclear reactors is virtually non-existent, all current decommissioning cost estimates for plants such as Seabrook involve a large measure of speculation.

Second, cost estimates for developing technologies have a demonstrated tendency toward "optimism", with cost over-runs routinely exceeding 100 percent of the original estimate. Decommissioning is a case of such a developing technology.

Third, engineering-based cost estimates for nuclear plant construction and operation have been consistently low, owing to the evolution of experience and regulatory requirements over time. This is particularly relevant to decommissioning which is likely to embody some of these problems specific to nuclear technology.

Fourth, decommissioning cost estimates have themselves been increasing rapidly since the first engineering estimates were made. For example, the four site-specific engineering decommissioning cost estimates done by Mr. LaGuardia in 1977 averaged $74 per kw (in 1994 dollars) and the 14 site-specific estimates done in 1993 averaged $465 per kw (also in 1994 dollars). The average annual growth rate over the 16 year period amounts to 12 percent real. Using a log-linear regression to determine the real growth rate for 157 estimates over the period 1977-1994 yields a real growth rate of 9 percent above inflation.

Fifth, while the LaGuardia estimates for the Seabrook unit have increased at a real rate of 2.4 percent over an 8 year period, from approximately $299 million (1994 dollars) in 1986 to $361 million (also 1994 dollars) in 1994, escalation rates for decommissioning nuclear plants of comparable size and type have increased at a substantially higher rate. For example, TLG decommissioning cost estimates over a ten year period for the nuclear plants Wolfcreek, Callaway, and Waterford-3 have increased at average annual rates of 9 percent, 7 percent, and 5 percent, respectively.

Sixth, regulations in the areas of nuclear waste disposal and nuclear plant decommissioning have been evolving at a rapid rate. Changing regulations have been identified as one factor contributing to the past increases in decommissioning cost estimates. Thus, as regulations evolve in the future, further cost increases for decommissioning can be expected insofar as such regulation will restrict the scope of choice in establishing decommissioning procedures and/or impose specific decommissioning tasks. This is particularly likely to occur as full-scale nuclear plants with significant operating periods actually begin to be decommissioned. Such regulatory impact could be similar to that already experienced in the building and operating of nuclear facilities.

Seventh, analysts such as EPRI and the Rand Corporation who have studied cost estimation for unproven technologies recommend that factors much higher than standard project contingency factors be applied in order to reduce the bias embodied in the technological optimism of early cost estimates for such technologies.

Eighth, given the ambiguity concerning DOE's future legal obligation to dispose of the most radioactive components of a nuclear power plant, including some of the reactor vessel internal structures, immediate dismantlement of large nuclear power plants is essentially unfeasible until a viable disposal option for this waste is available. The current Seabrook decommissioning cost estimate is understated by over $70 million of spent fuel storage related costs that have not been considered by NAESCO. Additionally, in the absence of low level waste disposal options for the state of New Hampshire over the longer term, LLRW may have to be stored on site throughout the duration of the plant's operating life. The current decommissioning estimate does not reflect the cost of disposing the *accumulated* LLRW stored on-site at the time of decommissioning, nor does it account for potential state surcharges or "access" charges that may be imposed for out-of-state disposal. These uncertainties pertaining to both high and low level waste disposal options for Seabrook suggest that the current estimate of the decommissioning cost and the low escalation rate assumed for Seabrook are optimistic.

Ninth, there is no evidence to date that the operating license period for any nuclear plant represents the energy-producing life of the plant. The basis by which the operating license period is established does not incorporate any scientific premises. It is overly optimistic for NAESCO to assume that Seabrook does not have the potential to experience serious technical, economic, and/or political difficulties before the end of its 36-year license period. One such example may be the possible negative impact that an increasingly competitive environment may have on electric utilities, which could prove too economically taxing for sustaining nuclear power generation.

Tenth, experience in the field of decommissioning has shown that some utilities have had to delay the prompt dismantlement decommissioning stage and use the SAFSTOR method as a combined result of unavailable disposal options for LLRW and/or HLRW and "premature" shutdown. For example, the Trojan unit in

Oregon and Yankee Rowe in Massachusetts were both originally planned for prompt dismantlement but have now been designated for SAFSTOR/delayed DECON decommissioning, for which the estimated costs are typically higher.

Eleventh, Mr. LaGuardia's cost estimate for Seabrook embodies both the strengths and the limitations of his earlier estimates, and of overnight engineering estimates in general. It is the latest in a series of TLG Engineering decommissioning cost estimates, each of which assumes: 1) a specific precisely defined scope of work; 2) no future evolution of regulation or technology; 3) no additions of equipment to the plant during its operating life; 4) hypothetical facilities for the disposal of low-level and high-level radioactive waste; and 5) a "conventional" contingency factor (ranging from roughly 25 percent to as low as 14 percent) which implies a great deal of confidence in the accuracy of current cost projections for decommissioning.

In summary, NAESCO's proposed plan for collecting the funds for decommissioning the Seabrook plant significantly understates the funding requirements by neglecting a variety of important cost considerations -- the consequences of which may raise the issue of prudent decommissioning fund planning on the part of NAESCO.

We recommend two alternative approaches to incorporating costs and shutdown date uncertainties. If a deterministic approach (i.e., based on a single set of assumptions) is to be used, then we recommend an assumed energy-producing life for Seabrook of 25 years, a 2 percent real escalation rate above the general inflation completion in 1962. This amounts to roughly $2,880 per kw in 1994 dollars. Per unit of capacity, this is in the ballpark of the costs of some recently constructed nuclear plants, despite Elk River's small size and early on-line date.

Factors that might imply higher costs per kw of capacity for a full-scale decommissioning than those derived by scaling the Elk River cost include the increases in waste disposal costs since 1978, longer shipping distances to a disposal site, problems in cutting and handling thicker materials, and additional problems of worker exposure in a more radioactive environment. The extent to which these factors will impact the costs of future decommissionings is uncertain.

Q. PLEASE DESCRIBE THE EXPERIENCE AT SHIPPINGPORT.

A. The Shippingport facility was dismantled over the 1985 to 1989 time period, at a cost of $91.3 million, or about $116 million in 1994 dollars. At 72 MW, this cost amounts to $1,611 per kw of capacity, roughly five times greater than the Seabrook estimate (1994).

Q. IS THE SHIPPINGPORT DECOMMISSIONING EXPERIENCE RELEVANT TO THE FULL SCALE DISMANTLEMENT PROJECTS THAT WILL TAKE PLACE IN THE FUTURE?

A. Yes. There is much to be learned from the Shippingport experience with regards to the general process of full scale dismantlement of nuclear units. There are however, several reasons to believe that the cost to decommission Shippingport may not be applicable to other plants. First, the NRC did not have regulatory oversight over the Shippingport decommissioning. Second, there had been significant clean up work done during the plant's operation, including clean up associated with two replacements of the reactor core. An OTA report notes that:

> At final shut down, the last Shippingport reactor core had been in operation only 5 years ... and the radioactivity in the reactor pressure vessel (RPV) was about 30,000 curies (Ci), which had decayed to 16,000 Ci when decommissioning began 3 years later. For comparison, the projected radioactivity levels in the RPV of an 1,175-MW PWR at shutdown (assuming 30 years of full power operation) have been estimated at 4.8 million Ci, about 300 times the amount at Shippingport when decommissioning began there.

A related third point is that the relatively low amounts of radioactivity, and the reactors pressure vessel's small size allowed for one-piece disposal. And finally, the Shippingport waste was sent to Federal facilities in Idaho and Washington state.

While both the Shippingport and Elk River actual dismantling costs are considerably higher than current engineering estimates for large plants on a per kw basis, caution is advised in extrapolating from this comparison for two reasons. First, there is no experience to date for the complete dismantlement of a large nuclear plant that has operated for a significant period of time. Second, every decommissioning cost estimate is based on a specific set of assumptions that include the type of decommissioning method to be used, the cost for waste burial charges, and various facility-specific factors that cause the cost on a per kw basis to differ.

Q. HAS THERE BEEN ANY OTHER EXPERIENCE WITH COMPLETE DISMANTLEMENT OF NUCLEAR PLANTS?

A. No. A number of nuclear units ranging in size from 170 MWe to 1,095 MWe were shut down between the period 1989 to 1992, specifically Fort St. Vrain, Yankee

Rowe, Trojan, Rancho Seco, and San Onofre 1. Of these facilities, only Fort St. Vrain in Colorado, and to a limited extent Yankee Rowe in Massachusetts, have begun dismantlement. The other units have been placed into the "safe storage" and/or delayed decontamination decommissioning stage, largely because there has been no option but to delay original plans for prompt dismantlement until disposal options for high level and/or low level radioactive waste become available.

Overall, the decommissioning undertaken to date has been relatively limited. Similarly, maintenance activities, although occurring in full-scale plants, have been limited to repair and replacement of particular plant components, and are not comparable to a complete dismantlement project.

Applying the current state-of-the-art technologies for decommissioning to full-scale decommissioning of a nuclear plant involves a tremendous increase in scale and complexity, representing a major challenge to nuclear plant managers, engineers, and workers. It is essential that the development of the technology continue so that it may be applied in decommissioning the existing nuclear plants safely and economically.

The lessons to be learned from decommissioning experience thus far support the emphasis made in this testimony. Specifically, that there exists a significant degree of uncertainty in the decommissioning process and that these uncertainties should be reflected in the decommissioning cost estimate and/or the associated escalation rate.

4. A BRIEF HISTORY OF DECOMMISSIONING COST ESTIMATION

Q. WHEN WAS THE FIRST ENGINEERING ESTIMATE OF THE COST OF DECOMMISSIONING A LARGE NUCLEAR POWER PLANT MADE?

A. The first engineering analysis of the decommissioning cost of a large nuclear power plant that we are aware of was published in 1976 by the Atomic Industrial Forum's National Environmental Studies Project (An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives, AIF/NESP-009, 1976). The cost at that time was estimated at \$26.9 million (in 1975 dollars for immediate dismantlement of a generic 1160 MW pressurized water reactor (PWR). This is equivalent to \$70 million (or \$59.7 per kw) in 1994 dollars. Mr. LaGuardia, of TLG Engineering, the consultant responsible for the Seabrook decommissioning cost estimates, was one of the authors of that report.

Q. WHAT TYPE OF ESTIMATING PROCEDURE WAS USED FOR THE 1976 STUDY?

A. The 1976 decommissioning cost estimate was an overnight engineering estimate. That is, it was developed by identifying the set of tasks to complete the project and then multiplying unit costs for each identified task by the number of times the task was expected to be required, as if the entire project could be planned with perfect foresight, and performed instantaneously, or "overnight". In other words, it was based upon a specific "design" embodying tasks, equipment, and personnel requirements developed under then current technology and unit costs. The effects of "unforeseen" difficulties and future cost escalation were not included in the 1976 cost estimate. Mr. LaGuardia's later estimates of decommissioning cost typically account for unforeseen but expected difficulties either by adding a 25 percent contingency factor to the base cost estimate, (as do the generic decommissioning estimates by Battelle), or by adding *line item* contingency factors typically amounting to somewhat less than 25 percent.

While we consider the conventional contingency allowance inadequate for current decommissioning project estimates, the 1976 study was particularly optimistic since it included no allowance for contingency.

Q. HOW HAVE MR. LAGUARDIA'S DECOMMISSIONING COST ESTIMATES CHANGED SINCE 1976?

A. I have compiled a database of 157 site-specific decommissioning cost estimates prepared by or under the supervision of Mr. LaGuardia. These estimates for decommissioning by immediate dismantlement (DECON) are plotted in Exhibit__(TEL-3).

The four estimates made in 1977 average $74 per kw (adjusted to 1994 dollars) while the fourteen estimates made in 1993 average $465 per kw (also in 1994 dollars). This is an increase of more than six times. The implied average annual growth rate is 12 percent. Rates of increase of this magnitude indicate the high degree of uncertainty in current decommissioning cost estimates which are developed in the same manner.

While the limitation of comparing cost estimates on a dollar per kw basis was making the site-specific engineering estimates the only alternative. While this caveat has general validity, time has demonstrated that where the engineering approach was used for this technology, it was the wrong choice. The use of a statistical approach based upon historic trends would have produced better projections, allowing better decision-making, and ultimately could have saved billions of dollars.

Q. CAN YOU PROVIDE A SPECIFIC EXAMPLE OF A STATISTICAL APPROACH TO COST ESTIMATION PROVIDING A MORE ACCURATE CONSTRUCTION COST ESTIMATE FOR A NUCLEAR PLANT?

A. William Mooz used a statistical approach to nuclear plant construction cost estimation in his work for Rand and DOE. Also, Tellus has used the statistical approach to project construction costs for dozens of nuclear plants. For all of these, the owners of the plants were relying upon engineering estimates. We are aware of no case in which the engineering estimate has turned out to be a more accurate projection.

One example where the two approaches were used at approximately the same time for the same plant is for Seabrook unit I. In March, 1982, Stone & Webster performed an analysis of Seabrook for one of the Seabrook owners, estimating the final cost of Seabrook 1 to be $2,219/kw. In April, 1982, Tellus performed an analysis for the Maine Public Utility Commission Staff in which we estimated the cost of Seabrook 1 to be $3,531/kw, 59 percent higher than the Stone & Webster estimate. The actual cost of Seabrook 1 was close to $4,000/kw.

Q. IN YOUR DISCUSSION OF THE GENERAL PROBLEMS THAT ARISE WHEN

OVERNIGHT ENGINEERING COST ESTIMATION IS APPLIED TO NEW TECHNOLOGIES, YOU HAVE DISCUSSED PARTICULAR EXAMPLES FROM THE EXPERIENCE WITH CONSTRUCTING NUCLEAR PLANTS. WHY ARE THESE RELEVANT TO NUCLEAR DECOMMISSIONING?

A. The general problem of overnight engineering estimation understating the final cost of large projects involving new technologies is directly relevant to nuclear decommissioning. Nuclear decommissioning is a new technology in general, and is particularly untried with respect to the dismantling and disposal of full-scale nuclear plants that have operated for many years. The Rand study's finding of widespread underestimation of costs for such new technologies should be accounted for in estimating costs for decommissioning.

The experience gained in estimating costs for nuclear plant construction and operation are also not to be ignored. The many important lessons to be learned include the following: first and perhaps most importantly, we now know that for a new or developing technology in an environment of evolving regulatory and public concern, cost estimates can be low by factors of as high as fifteen, and cost overruns can reach as much as billions of dollars for a single project (as experienced by the construction of Seabrook). This knowledge must be factored into current decision-making for the future.

Second, an alternative approach to cost estimation is available and has been applied successfully in the past. Under this approach, historic cost trends are analyzed and used in projecting future costs.

6. THE INADEQUACY OF THE SEABROOK DECOMMISSIONING COST ESTIMATE

Spent Nuclear Fuel

Q. ARE ALL COSTS ASSOCIATED WITH SPENT NUCLEAR FUEL (SNF) INCLUDED IN THE COMPANY'S DECOMMISSIONING ESTIMATE?

A. No. The decommissioning scenario assumed by TLG does not include the costs of storing SNF prior to acceptance by DOE. The Company assumes that all costs associated with dry cask storage after plant shutdown are not Seabrook Station decommissioning expenses. Furthermore, since the Company's estimate inappropriately assumes an early shutdown of the spent fuel pool, it does not include the total costs associated with fuel cooling requirements.

Q. IS IT VALID, IN YOUR OPINION, TO EXCLUDE THESE COSTS FROM THE DECOMMISSIONING ESTIMATE?

A. No. Section 111(a)(5) of the NWPA assigns the waste owners and generators the primary responsibility to provide for, and pay the costs of, interim storage until the SNF is accepted by the DOE. Therefore, all costs associated with SNF storage after plant shutdown and prior to DOE acceptance are the responsibility of the Company and should be considered as appropriate decommissioning expenses. To underestimate or ignore these expenses will engender inequities and jeopardize a safe and orderly decommissioning process.

Q. WHAT ARE THE SPECIFIC COSTS REGARDING SNF THAT YOU BELIEVE SHOULD BE INCLUDED IN THE COMPANY'S DECOMMISSIONING

ESTIMATE?

A. The specific costs that should be included are (1) operation and maintenance costs associated with a dry cask storage facility for the period 2026 to the end of SNF transfer to the DOE and (2) operation of the spent fuel pool for an additional 34 months beyond the December 2028 planned shutdown date.

Q. CONCERNING DRY CASK COSTS, WHY DOES THE COMPANY ASSUME THAT THE DOE WILL BEAR ALL COSTS ASSOCIATED WITH INTERIM SNF STORAGE AFTER PLANT SHUTDOWN?

A. The Company assumes that the DOE will bear all costs associated with dry cask storage, including designing, building, insuring, operating, and decommissioning these casks, because of recent action by the Secretary of Energy (Response to Question #18; First set of Data Requests from the Office of Consumer Advocate; NDFC 93-001). On February 18, 1994, Secretary O'Leary offered "guidance" to the Office of Civilian Radioactive Waste Management stating that in order to help offset costs incurred by the unavailability of a federal repository for spent fuel in 1998, DOE would, "to the maximum extent possible," provide multi-purpose casks (MPC) (which are suitable for storage, transport, and disposal) to utilities (Response to Question #7; First set of Data Requests from the Office of Consumer Advocate; NDFC 93-001).

Q. DO YOU CONSIDER THE SECRETARY'S STATEMENT TO INFER THAT THE DOE WILL BEAR ALL COSTS ASSOCIATED WITH SNF STORAGE AT THE SEABROOK STATION BEYOND PLANT SHUTDOWN?

A. No. First, the Secretary's guidance is primarily intended to provide storage cost relief to those nuclear plant operators who are most affected by slippage in DOE's waste acceptance schedule. This group of operators has been allocated storage capacity in the MRS facility starting in 1998 and will incur costs at that time that were heretofore not expected. In contrast, the first shipment of SNF from the Seabrook station is ranked low on the acceptance schedule and is not planned to take place until well into the next century. Secondly, the Secretary of Energy's guidance is not codified in law and as such carries no statutory authority. At this time, the Standard Contract between the DOE and the Company remains in effect and that contract clearly delineates DOE's responsibility to be transport and disposal of SNF, not storage. Finally, even allowing the assumption that the costs of MPCs will be fully covered by the Waste Fund, it is highly unlikely that the DOE will compensate the Company for ongoing operation and maintenance costs of the facility itself (i.e., staff salaries, radiation monitoring, security measures, etc). Therefore, all expenses associated with on-site storage of SNF during the period between plant shutdown and acceptance by the DOE of the last fuel assembly should be included as a decommissioning cost.

Q. DO ANY OTHER NUCLEAR UNITS TREAT THESE COSTS AS DECOMMISSIONING EXPENSES?

A. Yes. For example, the decommissioning estimate for Vermont Yankee includes these costs even though it also assumes that DOE will provide MPCs.

Q. CONCERNING SPENT FUEL POOL COSTS, WHY MUST THE SPENT FUEL

MIGHT ALLOW?

A. Yes. A contingency factor could, legitimately, reflect the effects of future developments and the possibility that the scope of the project has been misjudged in the engineering estimate. These future developments can be changes in regulations, technologies, or unit costs, or they can be the result of "new" tasks that become part of a decommissioning project as estimates are made in even finer detail and as actual decommissioning experience is accumulated. Examples of this type might include additional costs resulting from increasing tariffs for the burial of radioactive waste, additional costs to meet tighter future regulations with regard to residual radioactivity levels, additional costs to meet tighter future regulations for worker or public radiation exposure, and any "real" cost increases for the labor, supplies, and electricity required in the decommissioning process. These would be cost increases beyond the general rate of price inflation. We would also include items currently "overlooked" such as the cost of setting up or decontaminating a particular tool used in the decommissioning process.

Q. ARE THESE EVENTS IMPOSSIBLE TO PREDICT?

A. While the effects of changing technology and regulation, real cost escalation, and developing knowledge of the tasks required in a decommissioning are difficult to predict, the impact of these can be substantial and should not be ignored. The past can serve as a guide to the likelihood of and magnitude of future effects, particularly when the historic data is interpreted with a general understanding of <u>current</u> conditions with regard to the state of the technology and regulation.

Q. WHAT CONTINGENCY FACTOR DOES MR. LAGUARDIA TYPICALLY USE?

A. A contingency factor of 25 percent was assumed in many of Mr. LaGuardia's estimates. In recent years, he has used a disaggregated approach in which separate contingency factors are applied to individual components of the job. The weighted average of these individual or "line item" contingency factors is typically within the range of 15 to less than 25 percent. For the Seabrook study, a weighted average contingency factor of 17.14 is applied to the estimated decommissioning cost. This magnitude of contingency factor is "conventional" and appropriate for standard projects for which technology and regulations are reasonably well established.

Q. IS A 17.14 PERCENT FACTOR AN ADEQUATE CONTINGENCY ALLOWANCE FOR A FULL-SCALE NUCLEAR DECOMMISSIONING PROJECT?

A. No. An allowance of 17.14 percent is extremely optimistic, and does not provide a realistic estimate of decommissioning cost.

Q. WHY DO YOU CONCLUDE THAT A 17.14 PERCENT CONTINGENCY FACTOR IS INADEQUATE?

A. Our assessment that a larger contingency factor is necessary is based upon the considerations discussed in previous sections of this testimony. New technologies in general and nuclear technologies in particular have shown a clear tendency of cost overruns and rapid cost escalation.

Q. WHAT SORT OF CONTINGENCY FACTORS ARE USED FOR CONSTRUCTION COST ESTIMATES?

A. EPRI makes recommendations about the sort of contingency factors to use for cost estimation for construction projects. Exhibit__(TEL-8) includes a few pages reproduced from EPRI's *Technical Assessment Guide*. While these guidelines for project and process contingency are not intended by EPRI to apply to nuclear plant decommissioning, we believe they point toward the use of much higher contingency factors and/or higher than inflation escalation rates for decommissioning.

Q. BASED ON YOUR DISCUSSION OF THE LIMITATIONS OF OVERNIGHT ENGINEERING CONTINGENCY FACTORS, HOW DO YOU JUDGE THE ADEQUACY OF THE DECOMMISSIONING COST ESTIMATE FOR SEABROOK?

A. Apart from the underestimated cost for Seabrook due to the omission of certain high level radioactive waste storage costs discussed earlier, the current $361 million decommissioning cost estimate for Seabrook, in of itself, is inadequate. We recommend that a contingency factor of 20 percent *over* the conventional 17.14 percent factor be applied, for a total contingency factor of 40.57 percent.

Q. HAS ANY PUBLIC UTILITY COMMISSION REQUIRED THAT A CONTINGENCY FACTOR GREATER THAN A CONVENTIONAL CONTINGENCY FACTOR BE APPLIED TO A DECOMMISSIONING COST ESTIMATE?

A. Yes. In a 1987 decision, the California Public Utilities Commission found that a 50 percent contingency factor should be applied to the TLG decommissioning cost estimates for the Diablo Canyon Units 1 and 2.

8. THE INAPPROPRIATENESS OF ASSUMING SEABROOK'S LICENSED OPERATING LIFE FOR DECOMMISSIONING PLANNING PURPOSES

Q. WOULD YOU SAY THAT PLANT RETIREMENT DATE IS AN UNCERTAIN VARIABLE FOR NUCLEAR DECOMMISSIONING PLANNING PURPOSES?

A. Yes. With nuclear unit operating costs increasing steadily over the last two decades, we have reached a point where the continued operation of certain nuclear units is uneconomic. For some units, particularly those facing major capital investments for equipment replacement or upgrade, "early" shutdown has been found to be desirable. For example, a decision was made to retire San Onofre 1, based upon economic considerations. The unit had operated since 1967, and was facing a required expenditure of $135 million in repairs and safety improvement. The California Public Utilities Commission's Division of Ratepayer Advocates performed an economic analysis of San Onofre and found that continued operation was not cost-effective, and would increase overall ratepayer electricity costs by over $150 million (*Report on the Cost Effectiveness of Continued Operation of the San Onofre Nuclear Generating Station Unit No. 1*. CPUC DRA, September, 1991, revised October 1991). Similarly, the case for San Onofre parallels closely to the that of Yankee Rowe, which shut down before the termination of its licensed operating life.

Exhibit__(TEL-9) lists twenty nuclear units that have been shut down "prematurely", generally based upon assessments that the costs of continued operation outweighed the benefits. The retirement decisions of the past few years for a set of commercial reactors, some full scale, point toward the possibility that many nuclear units may fail to operate economically over their operating license periods.

James Hewlett, an economist with the Department of Energy's Energy Information Administration, has studied nuclear plant costs and the economics of nuclear plant life extension, and found that life extension "would result in cost savings only if both the level and escalation rate of the operating costs for the refurbished unit fall substantially from 1986 levels" ("A Cost/Benefit Perspective of Extended Unit Service as a Decommissioning Alternative", *The Energy Journal*, Vol. 12, 1991).

An Office of Technology Assessment study found that "long-term prospects for the 107 operating plants...are increasingly unclear..." and that "the owners of an increasing number of plants are examining the economics of continued operation versus early retirement as well in the face of an increasingly competitive electric utility industry." The OTA also concluded that "substantial uncertainty remains in decommissioning costs and the adequacy of decommissioning financing in cases of early retirement or rapid cost escalation." We have reproduced a two-page summary of the OTA's study here as Exhibit__(TEL-10).

Q. IS THERE A DIFFERENCE BETWEEN THE "LICENSED OPERATING" LIFE OF A NUCLEAR PLANT VERSUS ITS "ENERGY PRODUCING" LIFE?

A. Yes. The licensed operating life for nuclear plants is typically set at 40 years. There is no scientific basis whatsoever for choosing a 40 year operating life for nuclear facilities. For the most part, the licensed operating life for a facility is

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Yankee Atomic Electric Company (Yankee Rowe Nuclear Power Station)	Docket No. 50-029 Decommissioning

CITIZENS AWARENESS NETWORK'S AND NEW ENGLAND COALITION ON NUCLEAR POLLUTION'S PETITION TO INTERVENE AND SUPPLEMENTAL PETITION TO INTERVENE

I. INTRODUCTION

Pursuant to the Nuclear Regulatory Commission's ("NRC's" or "Commission's") order of October 23, 1995, 60 Fed. Reg. 55,069 (October 27, 1995), petitioners Citizens Awareness Network ("CAN") and the New England Coalition on Nuclear Pollution ("NECNP") hereby submit the following petition to intervene and supplemental petition to intervene regarding the proposed license amendment to approve Yankee Atomic Electric Company's ("YAEC's") decommissioning plan for the Yankee Rowe Nuclear Power Station ("YNRPS").

II. PETITION TO INTERVENE

A. CITIZENS AWARENESS NETWORK AND THE NEW ENGLAND COALITION ON NUCLEAR POLLUTION HAVE STANDING TO INTERVENE ON BEHALF OF THEIR MEMBERS.

In any proceeding for the issuance or amendment of an operating license for a nuclear facility[1], Section 189(a) of the Atomic Energy Act guarantees a hearing "to any person whose

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[1] Pursuant to 42 U.S.C. § 2243(b) (1990), Congress has directed the NRC to conduct a single hearing with regard to the construction and operation of a uranium enrichment facility.

(a) YAEC bases its decommissioning cost estimate in part on the assumption that a LLRW disposal site will become available in Massachusetts in the year 2003.[45] As discussed in Contention B(1) above, this assumption is unreasonable.

(2) YAEC also bases its decommissioning cost estimate on the assumption that spent fuel will be transferred to a dry storage facility between 1998 and 2000.[46] YAEC's decommissioning cost estimate assumes that a total of 26 Multi-Purpose Canisters ("MPCs") will be used for dry storage of spent fuel and that the Department of Energy ("DOE") will fully compensate YAEC for the cost of the canisters.[47] YAEC assumes that these canisters will be available in 1998 and that a full transfer of fuel assemblies from the spent fuel pool to the MPCs will be completed by December 31, 1999.[48] However, in light of significant DOE cutbacks that have affected both the DOE contractor's design for the MPC and DOE staffing levels, it is extremely unlikely that DOE will meet this schedule. It is also questionable whether DOE will be able to compensate YAEC for the casks. Other storage-only cask designs now under development for compliance with NRC standards

45 FSAR at 501-1.

46 FSAR at 501-1.

47 1994 TLG Study at 20. The cost of each canister is about $350,000.

48 Id. at 21.

range in cost from about $300,000 to $1,040,000.[49] Assuming that YAEC must purchase casks at least as expensive as the MPCs, the resulting increase in the decommissioning cost for Yankee Rowe would be about $8.5 million. YAEC has unreasonably failed to include such a cost in the decommissioning cost estimate.

(3) YAEC's decommissioning cost estimate assumes that at the latest, spent fuel shipments to the DOE would be completed by the end of 2018.[50] As discussed in Contention B(2)(a), this estimate is inconsistent with DOE projections and is generally unrealistic.[51] YAEC's decommissioning funding estimate should be revised to provide sufficient funding for a more realistic, i.e., lengthy, onsite HLW storage period.

(4) YAEC's decommissioning cost estimate is based on a grossly inadequate contingency factor of 12.3%.[52] An adequate contingency factor is a necessary and standard tool used in cost projections to plan for unforeseen future developments and the possibility that the scope of the project has been misjudged in the engineering estimate. Contingencies include unforeseen

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49 Wisconsin Public Service Commission, Final Environmental Impact Statement, Temporary Storage of Spent Fuels in Dry Casks, Unit 2 Steam Generator Replacement, Point Beach Nuclear Power Projects (August 1994).

50 FSAR at 200-12.

51 The factual statements in Contention B(2)(a) are incorporated herein by reference.

52 The 12.3% contingency factor is provided in a letter from H.T. Tracy (YAEC) to Morton B. Fairtile (NRC) (October 26, 1994).

changes in technologies, sequence of activities, or unit costs. They also include hidden costs that emerge as a project progresses.[53]

YAEC's proposed contingency factor of 12.3% is significantly below relevant industry guidelines.[54] For example, for general power construction projects involving "new concepts with limited data," the Electric Power Research Institute ("EPRI") recommends using combined project and process contingency factors of 50% or greater.[55] Because decommissioning a large nuclear power plant involves special uncertainties not common to construction projects, the appropriate contingency factor for decommissioning should be even higher.

Moreover, YAEC's own experience with the preliminary phase of decommissioning bears witness to the inadequacy of the pro-

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53 For example, between 1993 and 1995, the decommissioning cost estimate for the Rancho Seco plant in California took a sudden jump of from $364 million to $441 million -- 21% -- when previously undetected contamination was discovered in the plant's secondary side. TLG Services, Inc., Decommissioning Evaluation for the Rancho Seco Nuclear Generating Station at vi (August 1995).

54 Petitioners also question the accuracy of the 12.3% figure. Based on YAEC's cost estimates, Petitioners calculate that the contingency rate actually used by YAEC is 11.9%.

55 EPRI, Technical Assessment Guide, Volume 1, Rev. 7 at 5-6 (1993). Project contingency refers to the capital cost contingency factor that covers the cost of additional equipment or other costs that would result from a more detailed design. Process contingency refers to the capital cost contingency factor that is applied to new technology in an attempt to quantify uncertainty in equipment performance. Using EPRI guidlines, the minimum project contingency for a detailed cost estimate is 10%, and the minimum process contingency is 40%.

posed contingency factor. In 1992, YAEC estimated a total cost of $16.4 million (adjusted to 1994 $) for the first phase of the CRP (*i.e.*, decontamination, removal, packaging, shipping, and burial of the pressurizer and steam generators; and decontamination, removal, and packaging of the reactor vessel internals).[56] This estimate included a contingency of about $4.6 million (in 1994 $), or 28%. However, the actual cost of the first phase of the CRP was $28.9 million (in 1994 $) -- over twice the original estimate.[57]

Finally, there is no support for YAEC's claim that the contingency factor of 18.4% that it used in 1992 should be reduced based on the additional planning, analysis and experience gained during the CRP.[58] Although YAEC now has some limited experience with the preliminary phase of decommissioning, this experience does not reduce the numerous and significant uncertainties and hidden factors in the remaining decommissioning tasks at YRNPS. These uncertain and hidden factors include, for example, LLRW disposal fees, spent fuel storage costs, mixed waste disposal costs, and delays in development of technology of disposal facilities.

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56 1992 TLG Study at 42.

57 1994 TLG Study at 7.

58 Letter from H.T. Tracy to M. B. Fairtile (October 26, 1994).

(5) YAEC's decommissioning cost estimate does not include the costs of lead, mercury and asbestos abatement.[59]

b. Comparison between cost estimate and present funds inadequate. Although YAEC provides an updated decommissioning cost estimate, it makes no attempt to compare that estimate with the amount of present funds available for decommissioning. The only information YAEC provides is a brief description of the FERC-approved settlement with YAEC's customers for $235 million.[60] However, it is not clear whether YAEC has received that money, or what other funds YAEC currently has on hand for decommissioning funding. Moreover, although YAEC states that collections from the Power contracts are placed in an "independent and irrevocable" trust at a commercial bank,[61] it does not provide any information about the trust, including how much money is in it or whether all YAEC receipts go into that account.

c. Inadequate plan for assuring availability of funds.

The only decommissioning funding identified by YAEC in Section 501 of the FSAR consists of a $235 million settlement with

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59 See unnumbered attachments to letter from R. Mellor to M. Fairtile, re: Additional Information Regarding Updated Decommissioning Cost Study (November 2, 1994). The unnumbered attached pages in Mr. Mellor's letter refer to cost estimates for decontamination activities; abatement of asbestos, PCBs, lead, mercury, and freon; and demolition of concrete. Significantly, no cost estimates are provided for abatement of the hazardous materials, although they are listed as activities to be undertaken.

60 FSAR at 501-1.

61 FSAR at 501-2.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

before the

ATOMIC SAFETY AND LICENSING BOARD

Yankee Atomic Electric Company	)	Docket no. 50-029
(Yankee Rowe Nuclear Power Station)	)	Decommissioning Plan

Affidavit of Bruce Biewald

I, Bruce Biewald, being duly sworn, upon oath/affirmation state as follows:

1. Since 1989, I have been Senior Scientist for the Energy Group and Manager of the Electricity Program at the Tellus Institute, a non-profit consulting organization based in Boston, Massachusetts. I am an expert in energy economics, particularly with regard to the electric industry. As indicated in my attached resume, I have testified as an expert in numerous state regulatory proceedings, many of which involved nuclear utility ratemaking, cost-accounting, and decommissioning.

2. I am familiar with Yankee Atomic Electric Company's decommissioning plan and decommissioning cost estimates.

3. I assisted in the preparation of contentions in this proceeding submitted by Citizens Awareness Network, Inc. [CAN] and the New England Coalition on Nuclear Pollution [NECNP]. In particular, I provided economic information and analyses in support of the contentions. I also reviewed the contentions for accuracy of information relating to decommissioning costs.

4. I certify that the factual information in CAN's and NECNP's contentions regarding decommissioning costs is true and correct to the best of my knowledge, and the economic analyses therein are based upon

my best professional judgment. I am aware that if the foregoing statements are willfully false, I am subject to punishment.

DATED AT: Boston, Massachusetts, this 30 day of November, 1995.

Bruce Biewald

STATE OF MASSACHUSETTS
COUNTY OF Suffolk ss.

On this 30 day of November, 1995, the above named Bruce Biewald appeared before me and swore that the foregoing two page affidavit is true and correct to the best of his knowledge and belief.

Kim Philbeck
Notary Public
My commission expires: Nov 9, 2001

SEAL

Nuclear Power Plant Decommissioning: Cost Estimation for Planning And Rate Making

By STEPHEN S. BERNOW and BRUCE E. BIEWALD

Despite the inherent uncertainties in the projected life spans of nuclear power plants and widely disparate cost estimates for the safe decommissioning of those units, sufficient funds must be available when needed to assure the proper disposition of contaminated materials. The authors of this article analyze the differences between site-specific and generic cost estimates and suggest the use of process contingency factors as a means of providing more accurate projections of decommissioning costs.

New commercial nuclear power plants are generally expected to operate for thirty to forty years, after which they must be decommissioned. No large commercial nuclear power plant has yet been dismantled, and there are considerable uncertainties regarding the ultimate technical and financial requirements. Nonetheless, funds are now being collected from electric utility ratepayers for the eventual decommissioning of nearly all of the 85 plants currently operating in the United States.

Decommissioning a nuclear power plant includes draining its fluid systems; decontaminating pipes, equipment, and structural materials that have become radioactive; and, either immediately or after some delay period, dismantling the reactor and surrounding structures and shipping the radioactive waste to a low-level waste burial facility. Thus, it is expected that the site will be available for unrestricted use, possibly for another generating facility.

Stephen S. Bernow is director of research at Energy Systems Research Group, Inc., in Boston. He has supervised the development of ESRG's nuclear plant data bases and statistical analyses, and has testified in regulatory proceedings throughout the U. S. on electric utility economics, reliability, and rate making. He serves as Senior Research Fellow at the Beijer Institute Center for Energy and Resources Planning of the Royal Swedish Academy of Sciences. **Dr. Bernow** received his PhD degree in physics from Columbia University and taught at the university level for seven years before joining ESRG.

For most nuclear power plants, the amounts being collected for decommissioning are relatively small. Kansas provides a typical case, perhaps somewhat above average. In a September, 1985, decision, the Kansas State Corporation Commission ruled that ratepayers must begin to provide about $2 million per year to cover the ultimate cost of decommissioning the new Wolf Creek plant.[1] However, the decommissioning payments required in Kansas, and in most other states, are dwarfed by a recent decision in California. In March, 1987, the California Public Utilities Commission ordered Pacific Gas and Electric Company to begin collecting $26 million annually, for the decommissioning of *each* of its two Diablo Canyon nuclear units.[2] Why would California decide to set aside more than ten times as much money for nuclear plant decommissioning as Kansas or, for that matter, most other states in the country?

The answer to this question is twofold. First, the California commission's cost estimate for decommissioning Diablo Canyon is considerably higher than most estimates for other plants — double the Kansas estimate for Wolf Creek, for example. Second, it adopted a plan for collecting these decommissioning funds which calls for relatively high contributions in the early years of plant operation. This was not a casual or uninformed decision: Prior to the Diablo Canyon case, California regulators had already expended a great deal of effort examining decommissioning issues, both in a generic proceeding and in hearings related to the Humbolt Bay nuclear plant which has been shut down since 1976.

In this article, the following topics will be discussed:

- The importance of funding decommissioning adequately,
- *Field experience* with decommissioning,
- The range of decommissioning cost estimates and the advantages of site-specific estimation,
- The rapid increases in decommissioning cost estimates, the underlying reasons for such increases, and possible remedies, and
- Decommissioning cost collection plans.

The Importance of Adequate Funding

Given the uncertainty inherent in any estimate of nuclear plant decommissioning cost, the likelihood that actual costs will greatly exceed current estimates, and the problems that could occur if adequate funds are not set aside for decommissioning, responsible decision makers *should approach the issue carefully*. While increases in current electric rates to fund a project scheduled to take place in the distant future may be unpopular, there are nonetheless, important reasons to increase current funding levels for nuclear plants. The principal reason is to provide better *assurance that funds will be available* so that the decommissioning process can be carried out in a safe, orderly, and timely manner without exposing workers or the public to unnecessary risks, and without putting the utility in a position of financial stress. This is especially important in the case of premature retirement. A utility which experiences the unexpected loss of a *major nuclear generating facility could encounter some* financial pressure even without the additional cost burden of decommissioning.

Considerations of *intergenerational equity* also imply higher current funding levels for decommissioning. Because the projected lifetime of a nuclear plant is uncertain (at least 12 licensed nuclear power plants have been shut down after less than twenty years of operation), in the years following a premature shutdown ratepayers may be asked to pay for a shortfall in the decommissioning fund. One way to minimize this potential inequity is to structure the payments so that they are relatively larger in the early years, at least in real dollar terms.

.Finally, in order to promote *economic efficiency* all of the costs associated with operating a plant should be recovered during the operation of the plant. To defer acknowledgement of "back-end costs such as decommissioning could serve to impede rational and informed decision making.

The key to responsible planning for nuclear plant decommissioning is to estimate costs realistically, so that appropriate funding plans can be put in place. The need for realistic estimates of decommissioning cost presents a major challenge to planners, given the lack of actual decommissioning experience and the difficulties inherent in estimating costs for a large complex project expected to take place in the distant future.

Nuclear Power Plant Decommissioning Experience

While some valuable experience demonstrating the feasibility of decommissioning has been accumulated through the decommissioning of smaller nuclear reactors, and through the ongoing maintenance activities at operating nuclear power plants, there has been no field experience with dismantling large commercial nuclear reactors. The largest nuclear power plant that has been dismantled to date is the Elk River reactor in Minnesota. At 22 megawatts (Mw), this plant is about 2 per cent of the size of a typical modern nuclear generating unit. Further, it ran for four years rather than the 30- to 40-year lifetime expected for a new plant. For these reasons, the buildup of radionuclides at a large nuclear plant will far exceed the amounts faced by the dismantlers of Elk River.[3] Higher levels of radiation, along with other difficulties in dismantling a large reactor, could well lead to significantly higher costs per kilowatt (kw), offsetting potential economies of scale. Specifically, workers will require greater shielding and remotely operated tools will play a more important role.

The *construction* of the Elk River plant was completed in 1962 at a cost of about $2,200 per kw in today's dollars, comparable to the cost of some recently completed nuclear plants (both Wolf Creek and Diablo Canyon direct construction costs are within 10 per cent of this figure). The dismantling of Elk River was completed in 1974 at a cost of $646 per kw in today's dollars, roughly three times higher than most current decommissioning cost estimates for large plants, and nearly five times higher than the Wolf Creek decommissioning cost estimate used by the Kansas commission.

Recent Cost Estimates for Decommissioning

There is considerable uncertainty inherent in any cost estimate for a project expected to occur in the distant future, particularly when comparable experience is limited. Thus, it is not surprising that cost estimates for

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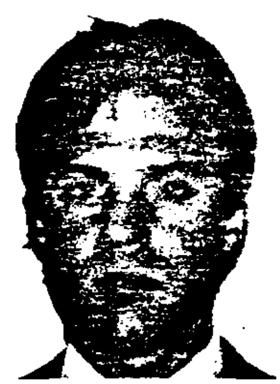


nuclear decommissioning differ greatly and, moreover, have been increasing rapidly.

In the July 19, 1984, issue of PUBLIC UTILITIES FORTNIGHTLY, Richard Buta and Robert Palmer[4] presented the results of a compilation of decommissioning cost estimates, which showed estimates made between 1979 and 1983 ranging from about \$50 million to \$220 million for pressurized water reactors (PWR), in 1983 dollars, whereas cost estimates made prior to 1979 were found on average to be significantly lower.

While outdated cost estimates below \$100 million are currently being relied upon for some plants, most *recent* site-specific cost estimates for the dismantlement of large nuclear generating units range from about \$140 million to \$250 million, in today's dollars. The Wolf Creek owners' estimate of about \$140 million for that 1,150-Mw plant falls at the low end of this range.

The California commission's estimate of \$289 million for each of the similarly sized Diablo Canyon units is about double the cost estimate adopted by the Kansas commission for the Wolf Creek plant. There are three primary reasons that the estimate for decommissioning Diablo Canyon is higher than the estimate for Wolf Creek: the larger inventory of materials at the Diablo Canyon plant, the date that the estimate was made, and the use of a higher "contingency factor."

Site-specific Decommissioning Cost Estimation

Both the Wolf Creek and Diablo Canyon decommissioning cost estimates are based upon *site-specific* engineering analyses. Such estimates are developed by identifying the inventory of materials and equipment at the plant, and multiplying the number of "items" in each inventory category by unit cost factors for removal.[5] Summing the component cost estimates for all of the equipment in the plant yields the total cost for "equipment dependent activities." Total decommissioning cost estimates also include the costs of radioactive waste transportation and burial, as well as "period-dependent activities" such as engineering staff, equipment rental, and insurance.

Because the Diablo Canyon plant has more material, its cost of decommissioning will naturally be higher than the cost of decommissioning a plant built of less material.[6] For example, the estimated volume of radioactive waste requiring burial was only 10,280 cubic yards for Wolf Creek compared to 12,168 cubic yards for each of the Diablo Canyon units.

Many utilities have estimated decommissioning costs for their nuclear plants by adjusting generic decommissioning cost estimates for "typical" plant designs, or by adjusting site-specific estimates prepared for other plants. This approach has tended to result in lower-cost estimates than the site-specific approach. It appears that in the process of developing detailed site-specific estimates, plant-specific decommissioning requirements (equipment or tasks) which might have been overlooked in a generic estimate are identified and incorporated into the cost estimate. Thus, a site-specific approach to decommissioning cost estimation provides additional accuracy, as well as the important function of identifying particular tasks and problems which might be encountered in the actual decommissioning. In effect, the site-specific estimate represents a preliminary engineering study of the project.

While a site-specific engineering estimate offers important advantages through the development of a detailed survey of the decommissioning process, this approach can lead to unwarranted confidence in the reliability of its results. At the present stage of development of the technologies and regulations, decommissioning cost estimates must be considered preliminary despite the level of detail that has been incorporated. One thing we have surely learned from cost estimates for nuclear construction projects is that attention to detail — i.e., disaggregation in the engineering estimates — does not in itself provide reliable cost prediction.

Trends in Decommissioning Cost Estimates

Since no large nuclear power plant has yet been dismantled, the costs and tasks involved in such a project are subject to considerable technical and regulatory uncertainties. Engineering estimates of the costs of implementing other large-scale, evolving, and uncertain technologies have often demonstrated a tendency toward "optimism."

Cost estimation for nuclear technology is a good example of this phenomenon. Engineering-based cost estimates for nuclear power plant *construction* and *operation* have been consistently low. A recent Department of En-

Figure 1

Nuclear Plant Construction Costs
Actual and Estimated

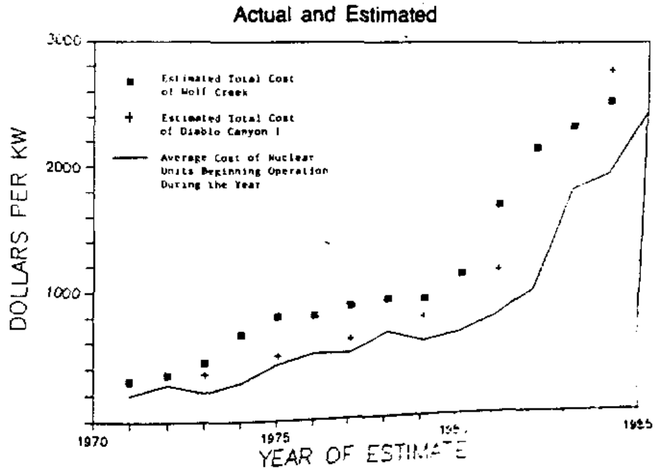
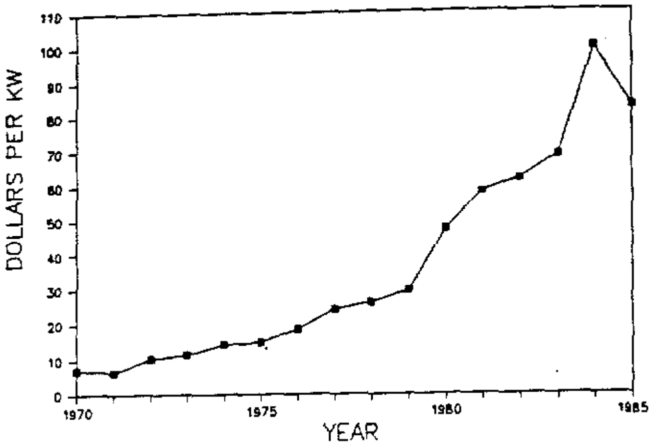


Figure 2

U. S. Industry Average Nuclear Plant
Nuclear Plant O&M and Capital Additions Costs



ergy report found that the actual construction costs of 75 nuclear plants with construction starts between 1966 and 1977 were about three times higher than the cost estimates at the start of construction (after adjusting for the effects of inflation and capitalized interest costs).[7]

The trend in nuclear plant construction costs since 1971 is shown in Figure 1. These costs have increased dramatically, with plants beginning operation in 1985 costing $2,421 per kw, roughly 12 times higher than the average cost of plants beginning operation in 1971. The annual rate of escalation during this period was 20 per cent, or 12 percentage points above inflation. Also shown in Figure 1 are the owners' series of cost *estimates* for the Wolf Creek and Diablo Canyon nuclear units, which were under construction for nearly all of this time period. These cost estimates and the actual costs of nuclear plants beginning operation at the time the estimates were made track fairly closely during this time period, with the estimated costs staying somewhat higher than the rapidly increasing actual costs of completed plants throughout the period. It is noteworthy that in 1971, at the beginning of this period, 24 commercial reactors were in operation. Thus, while the technology had certainly been demonstrated in "full-scale" projects, it was not yet "mature."

Nuclear plant operating and maintenance (O&M) costs and capital additions costs[8] have also tended to exceed expectations by increasing rapidly. Industry average nuclear O&M and capital additions costs are plotted in Figure 2 for the period 1970 through 1985. The average cost for nuclear plants in 1970 was $7.20 per kw, while in 1985 the average was $82.60 per kw. This elevenfold increase amounts to an average annual rate of escalation of 18 per cent, roughly ten percentage points higher than the general inflation rate.

When decommissioning begins on full-size nuclear plants, will it follow the pattern of nuclear plant construction and operations, with actual costs greatly exceeding estimated costs? The trend of rapid increases in decommissioning cost estimates over the past ten years suggests an affirmative answer. For example, cost estimates performed by a leading decommissioning consultant, Thomas LaGuardia, have increased from a 1976 estimate of $26.9 million to dismantle a "typical" large PWR to an average of $184 million for 12 estimates made in 1986 for large PWRs. This increase, roughly sevenfold in just ten years, represents an average annual rate of increase of 21 per cent.

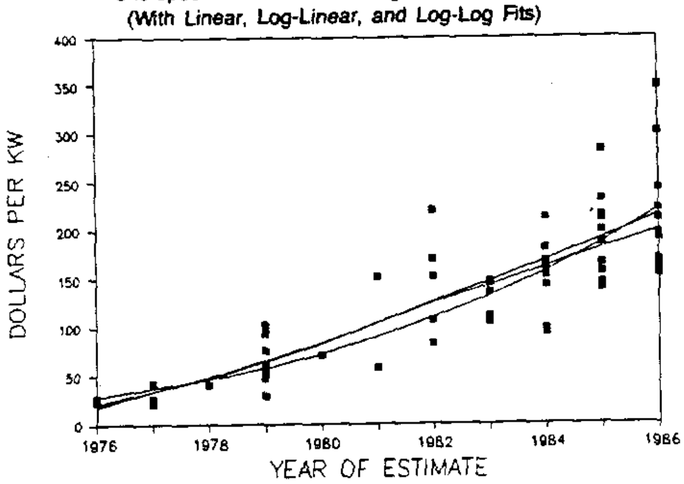
A data base of cost estimates prepared by or under the supervision of Mr. LaGuardia has been collected and analyzed by Energy Systems Research Group.[9] A graph of LaGuardia's cost estimates is provided in Figure 3, showing the individual estimates on a cost per kw basis, as well as the linear, log-linear, and log-log least-squares fits to this data. Statistical analysis of this data has indicated that the magnitude of the cost estimates is dependent upon the year in which the estimate was made, the type of reactor (PWR or boiling water reactor), and the size of the reactor.

All other things being equal, pressurized water reactors have been estimated to have about 20 per cent lower decommissioning costs than boiling water reactors. Moreover, while larger reactors are expected to cost more to decommission than smaller reactors, analysis of the estimates indicates that larger plants are expected to cost somewhat less on a cost per kw basis, reflecting some economy of scale.

The overwhelming factor in explaining the variation in decommissioning cost estimates, however, is the year in which the estimate was made. The log-linear fit shown in Figure 3 indicates that on average these engineering cost estimates have been increasing at a rate of 15 per cent per year above the rate of inflation.

Figure 3

Site-specific Decommissioning Cost Estimates
(With Linear, Log-Linear, and Log-Log Fits)



Reasons for the Rising Estimates

Why have decommissioning cost estimates been increasing so rapidly over time? A 1979 RAND Corporation study of cost estimation for new technologies found that for many energy process plants, cost estimates made when the technologies were "at an advanced stage of development" turned out to be "well over 100 per cent too low."[10] The same study examined cost estimating experience for weapons systems, public works and large construction projects, and chemical process plants, finding that "difficulties in estimating the capital costs of major projects are widespread," and that "capital cost estimates tend to display a low bias." Further research by RAND identified instability of the institutional environment as a major influence where actual costs exceed initial cost estimates by large margins.[11] Nuclear plant decommissioning is subject to institutional uncertainties related to environmental issues, worker health and safety, and labor practices, all of which are likely to influence its ultimate cost, just as similar conditions have influenced the costs to build and operate nuclear power plants.

All of the rapidly increasing cost estimates shown in Figure 3 are "overnight" engineering estimates, which assume that the decommissioning project takes place "instantaneously," according to a specific plan under today's technological and regulatory conditions. No attempt is made to account for "future" developments such as regulations that may emerge as actual decommissioning projects take place, equipment additions that can be expected during the plant's operating life, major unforeseen problems, and higher costs for the disposal of radioactive wastes in real rather than hypothetical disposal facilities.

The most frequently cited causes of nuclear *construction* cost increases have been the impacts of regulatory and technological changes resulting from experience gained through reactor operation. In the case of nuclear plant decommissioning, regulations have also been evolving at a rapid rate over the past few years, with specific regulations currently being developed by the Environmental Protection Agency and the Nuclear Regulatory Commission. As regulations continue to evolve in the future, further cost increases for decommissioning can be expected. This is particularly likely to occur as the first full-scale nuclear plants are actually decommissioned.

Regulatory and political developments with regard to low-level radioactive waste disposal are particularly relevant to decommissioning, since waste disposal costs comprise a significant fraction of total decommissioning expense.[12] Current overnight cost estimates typically assume a cost of about $30 per cubic foot for low-level radioactive waste disposal, reflecting tariffs at currently operating low-level radioactive waste disposal facilities. Increases in the cost of disposal are virtually certain, since the Nuclear Waste Policy Amendments Act of 1985 allows existing disposal facilities to exclude outside waste starting in 1993, and because any new facilities are required to meet new, and much stricter, federal regulations (10 CFR 61). Recent proposals by US Ecology and Westinghouse to the Central Interstate Compact put the cost of disposal at $89 and $95 per cubic foot, respectively (in levelized 1987 dollars). It should be noted that this compact has a relatively low waste volume (about 167,000 cubic feet per year), which increases the unit cost of disposal. On the other hand, the proposed fee structures for the Central Compact do not include preconstruction costs, which are substantial.

Current decommissioning cost estimates typically assume: (1) a precisely defined scope of work, (2) no future evolution of regulation or unforeseen technological problems, (3) no *real* price escalation, (4) hypothetical facilities for the disposal of radioactive waste, and (5) no additions of equipment to the power plant during its operating life. In effect, the current overnight engineering estimates fail to recognize both foreseeable future developments and the inevitable "surprises" that will emerge as full-scale nuclear plant decommissioning is actually attempted. It would be unwise to be caught by surprise once again, as the experience with nuclear power technology continues to unfold.

Cost Estimation: What Can Be Done?

As long as this approach, with its resulting unrealistic cost estimates is relied upon, frequent updates of any decommissioning cost estimate are essential, as an estimate can be badly out-of-date after a period of only a few years. However, regular updates should not substitute for improved cost estimation. To that end, it would be useful to apply realistic "contingency factors" to the engineering estimates of decommissioning costs, in order to anticipate increases that are likely to materialize.

Contingency factors are routinely applied to overnight engineering cost estimates in an effort to account for uncertainties that cannot presently be quantified, or, in some cases cannot be identified. For example, the effects of unfavorable weather, tool breakdowns, and changes in regulatory requirements can all be accounted for by a contingency factor. While difficult to quantify, or even identify precisely, the additional costs represented by the contingency factor are *expected*, given current and anticipated conditions. Part of the pr. lem with the series of decommissioning cost estimates to date is that they have not allowed for realistic levels of future technological and regulatory evolution. In fact they assume contingency factors that are far too low if the nuclear construction and operating cost experience and the RAND study, cited above, are taken as guides.

The Electric Power Research Institute's *Technical Assessment Guide* (EPRI P-4463-SR, December, 1986) offers guidelines for use in estimating the costs for "new and existing power generating technologies." EPRI recommends applying two separate contingency factors: a "project contingency" to cover the costs "that would result from a more detailed design of a definitive project at an actual site," and a "process contingency" to cover costs associated with the uncertainties of implementing a new technology on a commercial scale. For project contingency factors, EPRI recommends the following ranges as a function of the status of the cost estimate to which the contingency factor is to be applied:

	Recommended Project Contingency Factor
Simplified Estimate	30% to 50%
Preliminary Estimate	15% to 30%
Detailed Estimate	10% to 20%
Finalized Estimate	5% to 10%

With regard to the process contingency, EPRI recommends ranges depending upon the state of the development of the technology as follows:

	Recommended Process Contingency Factor
New concept with limited data	40% and up
Concept with bench scale data available	30% to 70%
Small pilot plant data available	20% to 35%
A full-scale module has been operated	5% to 20%
The process is used commercially	0% to 10%

The process contingency factor is to be applied to the base estimate *including* the project contingency, so that, for example, if 30 per cent were selected for both factors the combined total contingency factor would be 69 per cent; i.e., $1.3 \times 1.3 = 1.69$.

Engineering estimators of nuclear plant decommissioning cost have almost universally applied a contingency factor of 25 per cent. This allows for a variety of minor routine problems or inefficiencies. It can be compared with the 5 to 20 per cent contingency factors that are used in cost estimates for projects which have been fully demonstrated. Mr. LaGuardia, the engineer who developed the nuclear plant decommissioning estimates discussed above, has used a contingency factor of 15 per cent in estimating decommissioning costs for coal-fired power plants.

In testimony before the California Public Utilities Commission, the Energy Systems Research Group proposed that a contingency factor of 100 per cent be used in estimating the decommissioning cost for Pacific Gas and Electric Company's Diablo Canyon plant. In support of this higher contingency factor the observations discussed above were presented.

The California commission, in its decision in the case, compromised upon a contingency factor of 50 per cent for the Diablo Canyon units. This is the first regulatory decision in the U. S. in which a contingency factor of more than 25 per cent has been used for purposes of collecting funds for the ultimate decommissioning of a nuclear power plant. By applying a contingency factor that is higher than the more common 25 per cent figure, the California commission has taken a small but significant first step toward recognizing the likely costs of nuclear plant decommissioning.

Decommissioning Cost Collection

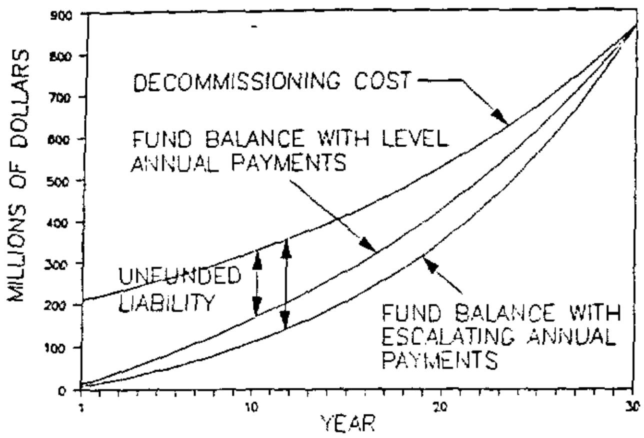
The California commission adopted a collection plan for Diablo Canyon in which level contributions are made into an external decommissioning fund. The external funding approach, in which the utility turns over the funds to a third party, offers better assurance that the funds will be available at the time of decommissioning than do internal funding approaches, in which the utility keeps the funds collected in either a segregated or unsegregated internal account. A discussion of the various funding approaches in the March 20, 1986, issue of PUBLIC UTILITIES FORTNIGHTLY discussed the various funding options, and noted that with the Tax Reform Act of 1984, the external approach has been offered special tax status which may make it the preferred option of both regulators and some utilities.[13]

Perhaps the most noteworthy aspect of the California commission's plan for collecting funds for decommissioning Diablo Canyon is the use of level payments in determining annual contributions to the fund. The Diablo Canyon funding plan is designed such that if the same amount in nominal dollars (about $26 million) is collected in each year of the plant's expected life, and if interest accrues at the expected rate, then at the time the plant shuts down the funds will match the currently estimated decommissioning cost (increased to account for inflation). Most utilities setting aside funds for decommissioning have structured the funding such that the payments start much lower but are expected to increase over time (in nominal dollars), even if the expected plant lifetime and decommissioning cost estimate do not change. This approach, adopted for Wolf Creek and most other nuclear plants in the U. S., provides much less assurance that funds will be available than does the level funding approach, particularly if early retirement becomes necessary.

In Figure 4, annual fund balances with level and with "escalating" funding plans are compared under a typi-

Figure 4

Decommissioning Cost Collection With Level And With Escalating Payments



cal set of assumptions. With the level funding approach, adopted for the Diablo Canyon plant, contributions to the fund in early years are higher, but the magnitude of the unfunded liability for decommissioning is decreased. Keeping the unfunded liability at a reasonable size can be important in the event of a premature shutdown of the plant.

Summary of Observations

The area of decommissioning cost estimation is full of potential problems for utilities, regulators, and ratepayers. Our analysis has indicated that:

- Decommissioning of large nuclear power plants is an untried process subject to a great deal of technological and regulatory uncertainty.
- The actual costs of large, complex, untried projects have routinely exceeded estimated costs by wide margins.
- Nuclear plant construction and operating experience have demonstrated that the costs of nuclear power plants have been subject to unwarranted optimism and rapid escalation.
- Overnight engineering estimates of decommissioning costs have rapidly increased over the last ten years.
- Radioactive waste disposal costs, a major component of decommissioning expense, have increased very rapidly in the past, and are likely to continue to increase in the future.
- Studies by RAND and EPRI provide a framework for situating decommissioning as a relatively uncertain process with a relatively high likelihood of cost increases.
- By applying appropriate contingency factors to engineering estimates of decommissioning cost, and by using a "level" funding approach, the risk of finding decommissioning funds to be inadequate is decreased.

Endnotes

[1]Kansas State Corporation Commission order in Dockets 120,924-U and 142,098-U 84-KG&E-197-R. The $2 million annual revenue requirement is the total for the three Wolf Creek co-owners: Kansas City Power and Light Company, Kansas Gas and Electric Company, and Kansas Electric Power Cooperative.

[2]California Public Utilities Commission Decision 87-03-029, March 6, 1987.

[3]The accumulated radiation at the shutdown of a typical large nuclear plant is expected to exceed 3 million curies, while the radiation accumulated at Elk River was only about 10,000 curies.

[4]"An Analysis of Decommissioning Cost Estimates for Nuclear Operating Plants," by Richard R. Buta and Robert E. Palmer, 114 PUBLIC UTILITIES FORTNIGHTLY 47, July 19, 1984.

[5]For example, the pumps that weigh between 1,000 and 10,000 pounds are counted. This number, multiplied by the unit cost factor for pumps in this size range, is the estimated cost for removing this equipment.

[6]The additional material at Diablo Canyon is due, at least in part, to additional structural requirements for plant construction in a region where earthquakes are common.

[7]"An Analysis of Nuclear Power Plant Construction Costs," DOE-EIA-0485, Energy Information Administration, Washington, D. C.

[8]Capital additions costs differ from O&M costs in that they represent plant investments for new or replacement equipment which are expected to remain in service for a period of years, and so are capitalized rather than expensed.

[9]This data was obtained through discovery in various regulatory proceedings. It should be noted that LaGuardia's engineering analysis served as the basis for both the Wolf Creek and Diablo Canyon estimates discussed above.

[10]Edward W. Merrow, Stephen W. Chapel, and Christopher Worthing, "A Review of Cost Estimation for New Technologies: Implications for Energy Process Plants," R-2481-DOE, RAND Corporation (Santa Monica, California, 1979).

[11]Personal communication with Edward Merrow of RAND Corporation (June, 1987).

[12]Electric Power Research Institute's report "Updated Costs for Decommissioning Nuclear Power Facilities" estimates that 38 per cent of the cost of dismantling a large PWR will be for the disposal of radioactive material (May, 1985).

[13]"Financing of Nuclear Decommissioning Costs," by Michael Nixon, 117 PUBLIC UTILITIES FORTNIGHTLY 57, March 20, 1986.